U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 241.

B. T. GALLOWAY, *Chief of Bureau.*

THE USE OF ARTIFICIAL HEAT IN CURING CIGAR-LEAF TOBACCO.

BY

W. W. GARNER,

Physiologist in Charge of Tobacco and Plant Nutrition Investigations.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 10, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "The Use of Artificial Heat in Curing Cigar-Leaf Tobacco," by Dr. W. W. Garner, Physiologist in Charge of Tobacco and Plant-Nutrition Investigations, and to recommend that it be published as Bulletin No. 241 of the Bureau series.

This paper presents the results of investigations which have been in progress for several years in the Connecticut Valley relating to the improvement of present methods of curing cigar tobacco. It has been demonstrated that by the use of artificial heat the curing can be successfully accomplished during the most unfavorable weather conditions, and methods for accomplishing this end are outlined.

The author desires to acknowledge his indebtedness to Mr. W. S. Pinney, of Suffield, Conn., who has made a study of tobacco curing for many years, for his enthusiastic cooperation in these investigations. Mr. Pinney has not only worked out many of the mechanical details of applying heat by means of flues, but has thoroughly demonstrated by tests conducted on a large scale the value of this method of utilizing artificial heat in curing cigar tobacco.

Respectfully,

B. T. Galloway,
Chief of Bureau.

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INTRODUCTION.

The term "curing," as applied to tobacco, is sometimes used to include all of the processes to which the leaf is subjected after it has been harvested in preparing it for the manufacturer. There are thus included three more or less distinct processes, namely, the curing proper (frequently spoken of as "barn curing"), the fermentation process, and the aging process. The term as used in this article relates only to the first-mentioned process, in which the tobacco is prepared for fermentation.

In general, it can be said that the cigar-tobacco industry has reached a high plane of development in this country. In some sections at least, highly intensive methods are applied, the soil is heavily fertilized, the most approved cultural methods are used, and the growing crop from beginning to end receives the closest attention. Nevertheless, the methods of curing this type of leaf now in use must be regarded as crude when compared with those followed with some other types, notably the bright flue-cured tobaccos, notwithstanding the fact that with this latter type the general cultural methods are far from satisfactory. It is true that great progress has been made in the construction of barns for curing cigar leaf and many of those now in use in the wrapper-growing sections are models of perfection, but the method of curing which has been in almost universal use in sections growing cigar tobacco is air curing; that is, no artificial heat is used during the progress of the process. As a result the prevailing conditions in the curing barn are more or less subject to all the variations of the outside weather conditions and good curing is largely a matter of chance. Furthermore, the fact that there has been no satisfactory means of controlling the conditions in the curing barn has made it impossible for growers to make much progress in learning just what these conditions should be in order to secure the best results in curing.

The growers of western Florida have long followed the practice of utilizing open fires made on the floor of the barn for reducing the

excessive moisture during wet or cloudy weather. This procedure, which has been more recently applied in connection with the growing of wrapper leaf under artificial shade, effectually prevents injury from the disease known as pole-sweat. Charcoal and well-seasoned wood are used as fuel, the fires being so managed as to produce as little smoke as possible. More recently open charcoal fires have come into extensive use in the Connecticut Valley in connection with the shade-tobacco industry, having been introduced by Mr. M. L. Floyd, of the Connecticut Tobacco Corporation. With these exceptions, however, it is only in rare instances that artificial heat is resorted to in curing cigar tobaccos.

CHANGES IN THE PROPERTIES AND COMPOSITION OF THE TOBACCO LEAF WHILE CURING.

That the properties of the tobacco leaf are greatly changed in the curing is well known to every grower, but the changes in composition which thus alter these properties and the necessary conditions for bringing about these changes are little understood. The leaf when harvested contains from 70 to 80 per cent of water, the greater portion of which is lost by evaporation during the curing. Nevertheless, curing involves much more than the mere drying of the leaf, for a leaf can be completely dried in a few minutes by applying sufficient heat and such a leaf does not show the properties of cured tobacco. In addition to the loss of water there is a marked loss in weight of other constituents of the leaf, usually amounting to 15 to 30 per cent of the weight of the cured product. Thus, a hundred pounds of green tobacco, containing, say, 75 pounds of water, will lose 4 to 7 pounds of dry matter in curing, in addition to losing more than 70 pounds of the water.

It is not necessary to enter into a consideration of the exact character of the changes involved in the loss of dry matter, but it can be easily demonstrated that these changes are dependent on the activities of the living cells of the leaf. If a green leaf be killed with chloroform, heat, or other means, such a leaf can not be cured. Curing, in fact, consists essentially in subjecting the living leaf cells to a process of gradual starvation under proper conditions. The loss in dry matter represents largely the material consumed by the cells in an effort to maintain life as long as possible and is analogous to the loss in weight of animals undergoing starvation. The evidence of these changes in composition brought about by the starvation and final death of the leaf tissue consists in the change of the green color to yellow and, finally, to brown, the change in texture and the development of elasticity, and other properties of cured tobacco.

THE NECESSARY CONDITIONS FOR GOOD CURING.

It is quite possible to dry the tobacco leaf without curing it, and it is also largely possible to cure the leaf without drying it. The two processes may or may not go hand in hand, depending on whether the existing conditions favor both processes. In practice the problem is to dry the leaf under such conditions as will best develop the desirable qualities of cured tobacco. It is to be remembered that if the living cells of the leaf are killed prematurely the curing is stopped once for all, although the drying may continue. Under ordinary conditions the leaf is killed by the loss of water, so it is essential that too rapid drying be avoided in order to afford an opportunity for the curing changes to take place. On the other hand, if the drying is too slow or is delayed too long the curing proceeds too far. The rate of drying is therefore one of the principal factors in good curing.

In addition to loss of water, the leaf cells may also be prematurely killed by excessively low or high temperatures or by mechanical injury, such as bruising the tissue in harvesting. No portion of a leaf which is prematurely killed by these or other means can be successfully cured. It follows that tobacco which is subjected to frost, freezing temperatures, or too high temperatures when artificial heat is applied, especially in the first stages, can not be properly cured.

Aside from the premature killing of the leaf tissue by extremes of heat or cold, the temperature plays a very important part in affecting the rate of curing. The curing proceeds very slowly or is stopped completely at temperatures below 60° F., while the drying may go on rapidly if the air entering the barn is dry; in other words, the leaf under these conditions is likely to dry without curing. On the other hand, curing proceeds very rapidly at 80° to 100° F., while the rate of drying can be controlled by regulating the humidity in the barn.

It will thus be seen that the necessary conditions for good curing are that the tobacco be placed in the barn in sound condition, that the temperature be kept sufficiently high to allow the curing changes to proceed normally, and that the rate of drying be controlled by regulating the humidity so as to avoid either too rapid or too slow drying. The matter of properly regulating the humidity in the curing barn is discussed in the succeeding paragraphs.

POLE-SWEAT, OR POLE-BURN.

Pole-sweat, or pole-burn, which is so well known in those tobacco-producing sections where artificial heat is not used in curing, is one of the results of too slow drying in the more advanced stage of curing. Pole-sweat is nothing more than the rotting or decay of the leaf and is analogous to the ordinary decay of organic matter of

either animal or vegetable origin. It is important to understand this fact fully, for it renders it an easy matter to recognize the stage of the curing when pole-sweat is to be looked for and points clearly to the proper remedy. The decay of the leaf is due to micro-organisms, or "germs," which are active only at moderate temperatures and in the presence of an abundance of moisture. There will be little or no pole-sweat so long as the temperature remains below 60° F. or the relative humidity is less than 85 per cent.

It is also important to remember that these organisms feed only on dead or dying tissue. So long as the leaf tissue remains alive there can be no pole-sweat. Under ordinary conditions the appearance of the yellow color on the leaf indicates that the cells are reaching the dying stage; hence, this is the stage where pole-sweat is to be expected. It is sure to develop if the temperature is warm and if the humidity in the barn is high. It will be seen that the most favorable conditions for curing are those which lead to pole-sweat, but it is also true that the real curing is practically completed when the stage for pole-sweat is reached, and these facts open the way for a simple remedy against the disease.

Most growers are familiar with the so-called "strutting" of the leaf as a forerunner of pole-sweat, which is a stiffening of the midrib and veins, causing the previously wilted leaf to stand out somewhat like an opened umbrella. This strutting has no direct connection with pole-sweat except that both are due to the same cause, namely, excessive humidity.

Stem-rot—that is, decay of the midrib—is also likely to appear in the later stages of the curing when the drying is checked by excessive humidity. This trouble is more common when the tobacco is harvested by picking the leaves from the stalk. In the later stages of curing, after the leaf has turned brown, damage may result from drops of moisture collecting on the leaf when the drying is checked, thereby causing discoloration, even though pole-sweat does not develop.

HOW TO PREVENT POLE-SWEAT

While it is true that pole-sweat is held in check by temperatures below 60° F., it is to be remembered that the curing is also stopped at low temperatures, while the drying of the leaf may continue. The only practicable remedy lies in the proper control of the humidity in the barn; in other words, there must be adequate means of removing the excessive moisture during periods of wet weather.

Many growers have an impression that ventilation is effective in controlling this disease, but it can be easily seen that if the outside air is saturated with moisture ventilation alone, however thorough it

may be, can not possibly reduce the moisture in the barn. Moreover, the degree of crowding together of the tobacco in the barn has an influence only in so far as this affects the moisture of the air, and a single leaf of tobacco placed in the barn will rot the same as if the barn were completely filled, provided the temperature and moisture conditions favor pole-sweat. To reduce the moisture in the barn in wet weather the relative humidity of the air in contact with the tobacco must be reduced, and the only practicable means of accomplishing this is by the use of artificial heat combined with properly regulated ventilation. The capacity of the air[1] for holding moisture is greatly influenced by the temperature. For each increase of temperature of 18 or 20 degrees the capacity is doubled; so that, for example, if the temperature of a given volume of saturated air is raised from 50° to 70° F., the relative humidity drops from 100 per cent to 50 per cent. It will be seen, therefore, that if sufficient heat is applied to raise the temperature in the barn 15 or 20 degrees, and if the air is constantly renewed by ventilation, the relative humidity will be kept down to only 50 or 60 per cent. Under these conditions the tobacco will dry even more rapidly than is the case on a warm, bright sunshiny day.

To so regulate the temperature and ventilation as to avoid pole-sweat and at the same time insure the best possible curing is a matter for which definite instructions can not be given, for the reason that so much depends on the varying outside weather conditions and on the character and quantity of the tobacco in the barn. Our experiments in the Connecticut Valley have shown conclusively, however, that pole-sweat can be easily and completely controlled by the combined use of heat and ventilation, no matter how unfavorable the weather may be, and it is only a matter of experience to determine the quantity of heat and the amount of ventilation required in any given case. To be assured of success under all conditions means must be available for raising the temperature in the barn, which must be reasonably tight, 15 to 20 degrees above the outside temperature when moderate ventilation is used. Where the heat is applied before pole-sweat begins it will usually be necessary to use only moderate amounts if the heating is continued until the tobacco has passed the danger point, whereas if the disease has already gained headway more drastic heating is required to check it promptly.

The mistake must not be made of applying too little heat or applying it for an insufficient length of time, for this will only aggravate

[1] It should be stated here, once for all, that, strictly speaking, the air can not be considered as having capacity for moisture, for the water vapor is in reality merely mixed with the air. It would be more correct to speak of a given space as being saturated with moisture, but the common phraseology is so firmly established and so much more readily comprehended that for our purposes it seems desirable to retain it.

the trouble. In no case where there is real danger of pole-sweat should the temperature in the barn be allowed to remain less than 10 to 12 degrees above that of the outside air, and moderate ventilation is likewise essential. The condition of the tobacco is the proper guide in all cases, and it is important to examine the leaf at intervals in all parts of the barn, and particularly in the upper tiers. The heated air tends to rise, and sufficient heat must be used to reach the top of the barn; otherwise the moisture from the tobacco in the lower tiers is merely carried upward and deposited on the cooler tobacco nearer the top.

THE EFFECT OF HEAT APPLIED DURING THE CURING PROCESS ON THE QUALITY OF TOBACCO.

In considering the use of artificial heat in curing cigar tobacco the question naturally arises as to the effect of the heat on the quality of the cured leaf. As a matter of fact, it is quite possible so to apply the heat as to produce no artificial condition; that is, it may be applied only when the weather is unfavorable, and in such a way as to create those temperature and moisture conditions which would prevail in the barn when the weather is just right for curing. In this case the principal use of the heat would be to prevent pole-sweat, and there is no reason to suppose that the result of the curing would be different from that obtained in favorable weather without the use of artificial heat.

On the other hand, the curing may be forced by the use of heat so as to hasten the process and materially affect the quality of the cured leaf. Bearing in mind that the rate of drying and the rate of curing may or may not go hand in hand, it is plain that uniformly satisfactory results in tobacco curing can never be assured until efficient methods of regulating the temperature and moisture in the barn are followed. Artificial heat not only furnishes a means of securing the most favorable temperatures for curing, but when combined with ventilation also constitutes the only practicable means of controlling the humidity.

The rate of curing greatly increases with a rise in temperature, and in general more thorough curing is obtained at higher temperatures, provided the leaf is not dried too rapidly. It follows that artificial heat when properly applied is highly favorable to the quality of cigar tobacco, for thorough barn curing is essential to the best development of flavor, aroma, and elasticity and, to a lesser degree, of color in the sweating or fermenting process.

Artificial heat probably shows the greatest effect on the color of the cured leaf. Heat in the presence of sufficient moisture greatly hastens the rate of curing, but when used in conjunction with ventilation it also greatly increases the rate of drying. At given temperatures the

extent of the changes in color occurring during the curing are controlled by the amount of moisture in the leaf, so that the use of heat and ventilation combined makes it possible to control to a certain extent the colors obtained. We have found in the course of our experiments that not only the depth of the color, but also its character, can be largely controlled by regulating the temperature and ventilation. Under the present method of curing cigar-wrapper tobacco, particularly when the leaf is cured on the stalk, the final color of the bright wrappers is normally a clear cinnamon brown, free from any greenish cast, but generally showing more or less tendency toward a reddish cast. The present demand is for a wrapper of rather dull finish, showing the lighter shades of brown overlaid with a faint olive but absolutely free from red. The recent rapid development in the Connecticut Valley of the method of harvesting by picking the leaves from the plant is due primarily to this demand for a wrapper of "Cuban finish." It has been demonstrated that artificial heat is an important factor in obtaining the best curing with this type of leaf.

FORCING THE CURE BY THE USE OF ARTIFICIAL HEAT.

The two most important reasons why artificial heat should be used in curing practically all tobaccos are that (1) this affords the only practicable means of preventing the decay of the leaf caused by excessive moisture during wet weather and (2) tobacco does not cure properly at low temperatures, however favorable the weather may be otherwise, a fact of special importance in northern tobacco districts. In the case of cigar-wrapper leaf another important consideration is that proper control of the moisture in the barn, which can only be accomplished by the use of heat combined with ventilation, is the most efficient means of securing desirable colors in the cured product. Where no heat is used it frequently happens that even after the curing is largely completed wet periods of weather bring the tobacco into such moist condition that the color is greatly darkened and the quality of the tobacco otherwise injured, while if cold weather prevails during the curing the leaf simply dries without otherwise developing the desired properties of cured tobacco. The curing of cigar tobaccos can never be placed on a satisfactory basis until the process has been rendered largely independent of weather conditions by the combined use of artificial heat and ventilation.

During the first stage of the curing, in which the yellow color develops, the principal value of the heat is to maintain a favorable temperature in the barn, and during this period care must be taken to avoid too rapid drying. It is evident that the barn must be reasonably tight, so as to prevent the rapid escape of the heat and moisture. On the other hand, the barn must have proper means of ventilation

during wet weather, otherwise the drying will be checked and there will be danger of pole-sweat when the second stage of the curing is reached. If the outside temperature is below 60° F., heat should be applied; if the weather is clear, little, if any, ventilation is needed, while in wet weather more ventilation is necessary. The aim should be to keep the temperature in the barn above 70° F. and to regulate the ventilation so that the tobacco will dry slowly until it is pretty well yellowed. The leaf will cure satisfactorily at any temperature between 70° and 100° F., and the exact temperature to be maintained in the barn will depend on outside weather conditions. To prevent too rapid drying in cold, dry weather, even with the minimum amount of ventilation, the inside temperature should not be much more than 10 or 12 degrees above that of the outside air, while in wet weather a difference in the inside and outside temperatures of about 15 degrees is desirable, the ventilation also being increased.

With favorable temperatures the necessary changes effected in the curing proceed much faster than is commonly supposed, even though this is not apparent to the eye, so that when heat is applied, if the leaf does not become dry during, say, the first 48 hours, there is no danger of injuring the color thereafter by rapid drying. Under these conditions the green color left in the leaf disappears as soon as the cured tobacco comes into case a few times; in fact, in our experiments the best colors have been obtained from tobacco which was still quite green when the curing proper had been completed.

After the first stage of the curing has been completed—that is, when the leaf has yellowed sufficiently—whether or not the further use of heat is desirable depends mainly on the prevailing weather as to humidity. This is the period for pole-sweat, and if there is much damp weather the heating will need to be continued, while with favorable weather the curing can be completed without the further use of heat. In any event, however, the tobacco at this stage should be allowed to soften well before proceeding with the drying, and it is well to allow the leaf to come into good case from time to time until the midrib is cured. If, because of lack of barn room or other reasons, it is desired to hasten the second stage of the curing, heat can be freely used without fear of injuring the quality of the tobacco.

While it is true that the occasional softening of the tobacco during the second stage of the curing greatly improves its appearance, growers as a rule do not fully appreciate the serious injury to the color caused by allowing the cured tobacco to become too damp. Each time a cured leaf becomes damp the color is not only darkened, but loses in clearness and, besides, the tobacco undergoes a sort of cold

sweat which interferes with its normal fermentation in the packing house. This injury can be easily avoided by drying out the tobacco with artificial heat during wet or damp weather.

The suggestions here outlined regarding the use of artificial heat in curing have been worked out by experiments with wrapper leaf harvested by picking the leaves from the stalk, but the same principles can be applied to curing on the stalk, the main difference being that the curing will necessarily require more time. In our experience with picked tobacco, as has already been stated, in addition to avoiding direct injury to the quality of the leaf from unfavorable weather conditions, it has been found that the use of artificial heat gives the desired brown color, free from red and of dull finish.

METHODS OF APPLYING ARTIFICIAL HEAT.

We have pointed out the necessity of having available some suitable means of applying artificial heat, in order to control the temperature and moisture conditions in the barn, if the best results in curing are to be obtained. This brings us to a consideration of practical methods of applying heat and the requirements which these methods must meet. In cold, dry weather the curing ceases but the drying continues, while in warm, wet weather the curing proceeds rapidly and the leaf may even decay because the drying is stopped. A practical heating system must, therefore, be capable of controlling both the temperature and humidity so as to avoid these extremes.

No heating system will give satisfactory results in a barn which is not reasonably tight, for the temperature in such a barn can not be raised sufficiently without drying the tobacco too rapidly. On the other hand, a system of ventilators which can be opened and closed at will is necessary for the removal of the excessive moisture in the barn in wet weather. If there is no ventilation the air in the barn soon becomes saturated, and heat alone is of little or no value in this case. When artificial heat is used it is not desirable in filling the barn with tobacco to leave open spaces or vents from top to bottom, for these merely serve as channels for the escape of the heat to the top of the barn, while to be effective it must be forced to pass through the tobacco.

The heating system must have sufficient capacity. A little heat is frequently worse than none, particularly in the control of pole-sweat. Experience has shown that a satisfactory system must be capable of maintaining the temperature in the barn from 15 to 20 degrees higher than that of the outside air when moderate ventilation is used. It is only necessary to maintain this difference in temperature, however, when there is danger from pole-sweat, and under ordinary conditions a difference of 10 or 12 degrees between the inside and outside air is

sufficient. The heat must be applied at the bottom of the barn and must be evenly distributed in order that, so far as possible, all of the tobacco may receive the same amount.

As is well known, artificial heat has long been used in curing certain types of export and manufacturing tobaccos. There are essentially two methods of applying the heat. In the case of the so-called dark fire-cured export tobacco open fires are made on the floor of the barn and the smoke is allowed to pass up through the tobacco, thereby imparting a characteristic odor and taste to the leaf. No heat is applied for the first few days and thereafter the fires are maintained only at intervals, so that the tobacco is only partially cured with artificial heat. In the case of flue-cured manufacturing tobacco, the heat is introduced by means of furnaces fitted with a system of flues through which the heat is distributed. This method differs from fire curing in that the smoke does not come in contact with the tobacco and the heat is applied continuously throughout the curing. The process is completed in from three to five days. In flue curing, the temperature can be controlled with exactness, and this is decidedly the most perfect system of curing now in use. In both flue curing and fire curing wood is the fuel used.

It has already been stated that open fires have long been used in curing cigar tobacco in western Florida, and both wood and charcoal have been used as fuel. In curing shade-grown cigar-wrapper leaf in the Connecticut Valley open charcoal fires are quite generally used. The application of open fires and of heating by means of flues is considered in the following paragraphs.

THE USE OF CHARCOAL IN CURING.

The evident points in favor of open fires as a source of heat in curing are simplicity and cheapness, provided the fuel used is not expensive. Where wood can be used this is the cheapest method of applying heat, since wood is in most cases still a comparatively cheap fuel and open fires require almost no special equipment. Charcoal is generally preferred for curing cigar tobacco, however, for the reason that it burns with very little smoke. On the other hand, charcoal is one of the most expensive of fuels and the supply is limited and uncertain. It is an established fact that even cigar-wrapper leaf is not injured by small quantities of smoke, so that thoroughly seasoned wood, corncobs, and similar materials which burn with but little smoke can be used successfully in an emergency. Of course, any material which burns with dense smoke will cause serious damage by discoloring the leaf with soot. Coal and coke can not be used for open fires because of injurious gases, mainly sulphur dioxid, formed in combustion.

One of the principal difficulties to be met in using open fires is in securing an even distribution of the heat. The tobacco hanging directly over the fires will be overheated, while that between the fires is not likely to receive enough heat. Evidently a large number of small fires is better than a few larger fires, and they should not be more than 6 or 8 feet apart each way. It will be seen at once, however, that the labor required in taking care of the larger number of fires will be greatly increased. The small fires require close attention to keep them going and to avoid the danger of burning the barn. If the bottom tier of the barn is filled the tobacco hangs so near the ground that the fires are not easily accessible. In any case the tobacco hanging immediately above the spots chosen for the fires must be removed before these are started. Small heaters are occasionally used for burning charcoal, but these are of doubtful value except that they lessen the danger of accidental fires, and the same may be said of small pits dug in the floor of the barn, which have been used by some. Deflectors of various kinds are frequently suspended above the fires to secure a better distribution of the heat, and these are serviceable, but less so when constructed of metal, because they then transmit the heat very readily. They are most efficient when flat or having the shape of an inverted cone.

Open charcoal fires have thus far been used mainly in curing shade-grown tobacco, all of which is harvested by picking the leaves from the stalk. The method commonly used is to keep the fires going for about three days or until the leaf is pretty well yellowed, after which no heat is used except to prevent damage from pole-sweat in wet weather. During this period the approximate range of temperature in the barn is from 80° to 100° F., depending, of course, on the outside weather conditions. As a rule, the barns are kept tightly closed during the firing to prevent the tobacco from drying too rapidly. The roof of the barn being covered with shingles and therefore affording considerable ventilation and this class of tobacco being very light in body make it possible to dispense with ventilators on the peak, although these are undoubtedly very desirable in northern latitudes, as, for example, in the Connecticut Valley. The quantity of charcoal required for curing shade-grown tobacco will naturally depend very much on weather conditions, but with normal seasons there will usually be required from 200 to 300 bushels for a barn holding 5 acres of tobacco. With unfavorable weather conditions much larger quantities will be needed.

For curing ordinary picked tobacco, particularly the broadleaf, which is especially liable to develop pole-sweat, much more fuel will be required because of the greatly increased amount of water to be removed from the barn. For curing on the stalk still more heat will be required if the curing is to be forced, as is done with the shade-

grown leaf, and it is doubtful whether charcoal could be used except at prohibitive cost unless the heat is employed merely to temporarily ward off pole-sweat.

THE USE OF FLUES IN CURING.

Because of the difficulties attending the use of charcoal fires for forcing the cure of cigar tobaccos, more particularly the ordinary picked and stalk-cured types, which have been pointed out previously, experiments have been conducted during the past few years in the Connecticut Valley with a view to devising a more economical and satisfactory method of applying heat. The possibilities of steam heating were first investigated, but it was found that such a system is impracticable because of its cost. Attention was next turned to the use of flues, such as are employed with other types of tobacco, and with much better success.

As shown in figure 1, the heating system used in flue-curing districts consists of sheet-iron pipes 10 to 15 inches in diameter, leading from furnaces placed at one end of the barn. The flues extend across the barn and in returning pass out through the side of the barn, with a short smokestack at the end. It will be observed that the flue-curing barns are quite small, so that the heat is uniformly distributed. The aim of our experiments has been so to modify this method of heating as to make it applicable to the curing of cigar tobacco.

One of the first changes necessary in adapting this system to cigar leaf is that the furnaces shall be placed wholly on the inside of the barn. This prevents unnecessary loss of heat, greatly reduces the danger of setting fire to the barn, and protects the fire box from being flooded during rainy weather. Since the furnaces need to be set up permanently, they must be placed in the ground in order that they shall not interfere with the work of handling the tobacco and also that the necessary grade can be given the flues.

Since the high temperatures used in the flue-curing districts are not needed in curing cigar tobacco, the flues should not be so large. Experience has shown that those having a diameter of 8 inches are quite satisfactory. In the flue-curing districts the flues are made of light-weight black sheet iron and will last for many years, but in the Connecticut Valley it has been found that such flues will scarcely last more than one season. Galvanized iron of No. 24 gauge is recommended as a satisfactory material for constructing durable flues. Flues of this material will weigh something less than 3 pounds per foot. To facilitate setting up the flues and to avoid the danger of fire from loose joints the short pieces of pipe should be riveted together into long sections. It is important to have the open joints of these long sections made so that they can be easily connected, and they should be provided with "boot straps" for tying together securely

with wire. The joints ordinarily made by the manufacturer fit so tightly that it requires much time and patience to put them together.

Thus far wood is the only fuel which has been found suitable for heating the flues, and the furnaces have been designed more particularly for this fuel. In the system which has been developed the 16-foot sections formed by posts, frames, and girders set up across the barn and known as "bents," are taken as the unit, so that each

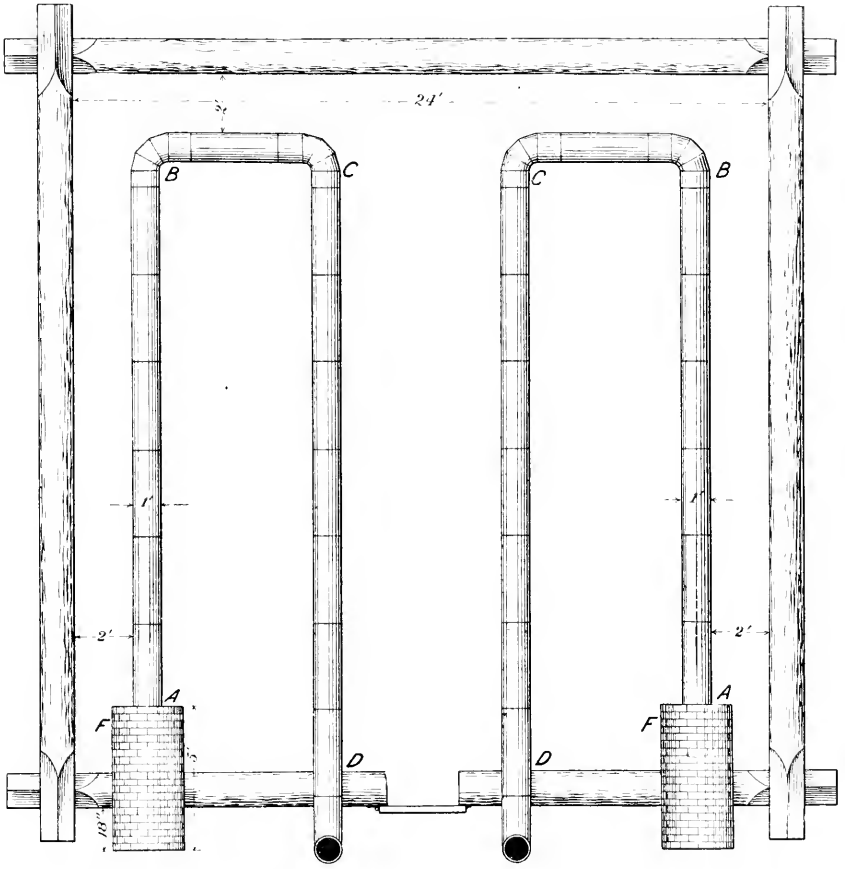

FIG. 1.—Sketch showing the arrangement of furnaces and flues in a barn adapted for curing yellow tobacco: *F*, *F*, Brick furnaces; *A*, *B*, *C*, *D*, sheet-iron flues.

section, or bent, requires an independent furnace and set of flues. The furnace, which is set in the ground, should be not less than 5 feet long and about 16 inches wide, inside measurement. The top should slope upward from about 16 inches at the front to, say, 26 inches at the back. The sides and the closed end may be made by laying a single thickness of brick without cement of any kind along the sides of the pit dug for the purpose, sheet iron fitted with a collar for receiving the end of the flue and covered with 2 or 3 inches of soil

serving as a top. Such a furnace, however, is not durable and is comparatively expensive.

A very cheap and desirable type of furnace, made of concrete cast in sections, is shown in figure 2. Sand and trap rock were used in casting these furnaces and the formula used was that ordinarily employed for mixing "strong" concrete. The top, sides, and end are all 4 inches thick and of the dimensions given in the preceding paragraph. The sides are cast with a 2 by 4 inch notch at the rear end for receiving the back. The top is reenforced with steel and is provided

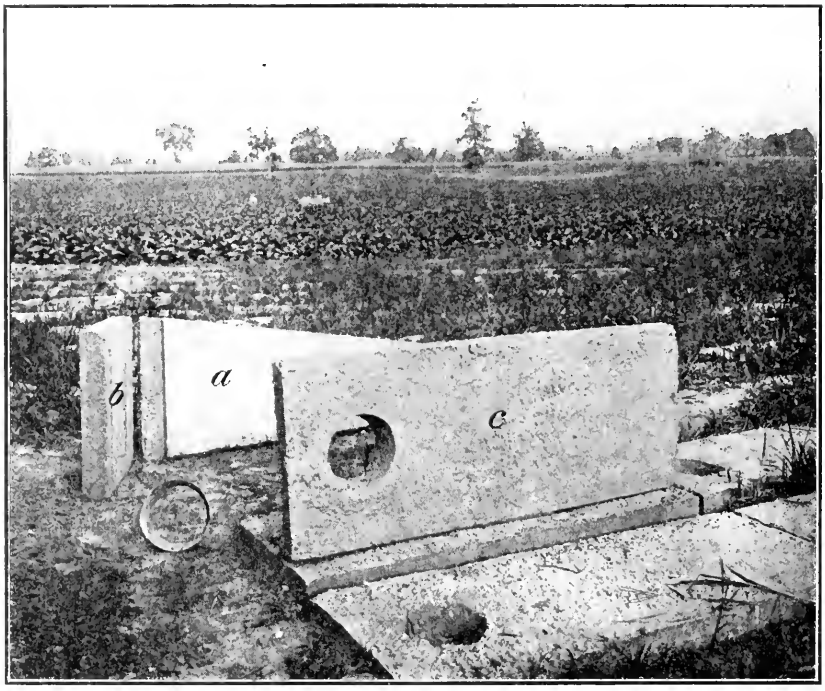

FIG. 2.—Type of concrete furnace, cast in sections, for use in applying artificial heat through flues, devised by W. S. Pinney, Suffield, Conn.: *a*, Side of furnace, with sloping upper edge and recess in rear end for receiving the end of furnace; *b*, *c*, top, with tapered opening at rear end for receiving end of flue.

with an opening, tapering downward, 6 inches from one end for receiving the end of the flue. The top is cemented on at the time of setting up the furnace. The sections of the furnace are heavy, and should be cast in the barn in which they are to be used. If the sand and rock can be had near at hand a furnace of this type would cost only about $1.50, exclusive of labor. In tests during the past season these furnaces gave very satisfactory results, and there is reason to believe that if properly made they will prove very durable.

In the system of heating which has been developed with the bent as the unit, figure 3 shows the best method which has been devised

for setting up the flues. The furnaces may be made to run either lengthwise or crosswise of the barn. They are all placed on one side of the barn, preferably on the north or west side. To prevent the excessive radiation of heat from the front end of the furnace the lower portion of the opening should be kept closed. This can be conveniently done by means of a piece of L-shaped sheet iron, of the width of the furnace, which will close about one-half the mouth of the furnace. By closing the lower portion the air is forced to enter through the upper portion of the opening, which does not interfere with the draft but prevents the escape of heated air from this end of the furnace.

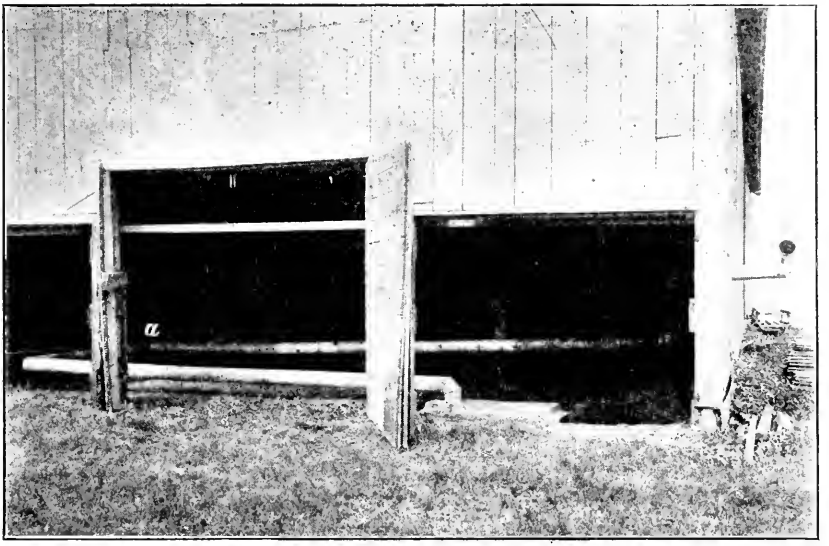

FIG. 3.—Furnace and flue in position. At *a*, a T-section may be inserted, the open end of which passes out of the side of the barn, thus preventing a back draft when the wind blows into the end of the flue. A separate furnace and set of flues, as shown, are required for each bent of the barn.

The first section of the flue running across the barn from the furnace can be riveted together into a single piece, while the return portion can be made of two sections, exclusive of the upright bend near the point of exit. This rise at the outer end of the flue is to facilitate passing from one furnace to the other and also to secure a better draft in the pipe. The elbow on the end is not essential, but is helpful in windy weather, as it can be turned so that the open end is away from the wind. The best method of supporting the flues is by means of a light-weight chain and small S-hooks suspended from the tier poles, making it possible to regulate quickly the grading of the flues. About 36 feet of chain are required for each bent.

The system set up as described works very satisfactorily, except when there is a strong wind blowing directly into the open end of the flue. In this case the flues can not be made to draw. This difficulty is overcome by using a T-section, fitted with a damper, for connecting the return portion of the flue with the end portion—that is, at the corner farthest removed from the furnace (see fig. 3, *A*). This section will automatically check the back draft caused by the wind blowing into the open end of the pipe by furnishing an exit for the surplus smoke. The end portion of the flue connecting the two runs across the barn can be riveted together into one section, including the elbow at one end and the T-piece at the other.

With a properly constructed barn this system of heating is easily capable of maintaining a temperature 20 degrees above that of the outside air. It is estimated that from 1 to 2 cords of wood will be required for curing an acre of picked tobacco. Some idea of the relative cost and heating value of wood as compared with charcoal can be had from the following data: The average weight per cord of wood of various kinds, such as oak, hickory, pine, chestnut, etc., is about 3,000 pounds, yielding about 32 bushels of charcoal, which weigh approximately 700 pounds. The quantity of heat obtained from 3 pounds of wood is approximately equal to that obtained from 2 pounds of charcoal, so that a cord of wood will yield about three times the quantity of heat obtained from the same quantity of wood after being converted into charcoal. The present price of charcoal in the Connecticut Valley is equivalent to a price of $12 to $15 per cord for wood. It is considered that the system of heating with flues which has been outlined will cost, complete, about $20 per bent, or, approximately, $35 per acre. The equipment with minor repairs will last many years, and it has been shown that it may pay for itself in a single season of bad curing weather.

It has been conclusively proved by Mr. W. S. Pinney and others through tests carried out on a large scale in the Connecticut Valley during the past two years that this system not only removes all danger from pole-sweat, but produces tobacco of the highest quality in all respects, particularly when applied to tobacco harvested by picking or priming the leaves. It is very probable that the method of constructing and arranging the furnaces and flues which has been described will be materially improved upon, and there would seem to be possibilities in developing a plan involving the use of one or more central smoke-stacks or chimneys extending through the roofs, into which the various flues can be led. What it is desired to emphasize more particularly is the fact that it has been convincingly demonstrated that the use of flues for applying artificial heat affords the best method yet devised for curing cigar tobacco, especially for curing the picked leaf.

In view of the fact that wood is not always easily obtainable it is highly desirable that some method of heating be devised whereby coal can be used, for this is a standard fuel which can be had in unlimited quantity. It seems possible that coal can be used for heating a system of flues if a forced draft is employed, but this would require some sort of motive power.

BARNS ADAPTED TO THE USE OF HEAT IN CURING.

It has already been pointed out that ventilation in conjunction with heat is required to control properly the humidity in the barn. The barns most used in curing shade-grown tobacco are high and have a steep shingle roof. Air can penetrate the shingle roof rather freely, which makes it possible to utilize charcoal fires without the use of a roof ventilator, but, nevertheless, the curing conditions could be better controlled with such a ventilator. In curing with flues, especially in the case of tobacco other than shade grown, the leaf of which is much larger and heavier in body, the roof ventilator is very important. Moreover, lower barns with flat roofs are much more desirable, for it is very difficult to force the heat through the green tobacco in high barns with steep roofs. Moderate-sized barns which can be filled in a day or two, so that the heat can be applied promptly, are preferred to larger ones. In the case of large barns, however, to fill which requires several days, temporary partitions can be put in at convenient intervals by tacking up strips of burlap on the cross framing. The burlap partitions, which are very effective in preventing the escape of the heat, make it possible to run the furnaces in one section while the next is being filled.

In figure 4 is shown a 7-bent barn with a low, flat roof of paper, designed by Mr. W. S. Pinney, of Suffield, Conn., which is especially adapted for curing the ordinary types of picked wrapper leaf. It will be noted that in addition to the regulation side ventilators a special ventilator extends along the peak of the roof, which opens on each side. The doors on either side can be opened or closed from the ground by means of ropes and pulleys. While heat is being applied all side ventilators are tightly closed, except the horizontal ventilator at the bottom, through which such air as is needed for ventilation is introduced. In operating the roof ventilator the principal point to be observed is to open only the side away from the wind. In dry weather comparatively little ventilation will be needed and frequently none at all, while in wet weather ample opportunity for the circulation of air must be given.

The aim should be to allow the air to enter the barn near the ground and, after being heated by coming in contact with the flues, to pass upward through the tobacco and finally to pass out through the roof ventilator. This is in accordance with natural laws regulating the

circulation of air as affected by temperature. The sole object is to so regulate the heat and ventilation as to secure the proper temperature in the barn for curing and so to control the humidity that the tobacco will not be injured by drying either too rapidly or too slowly.

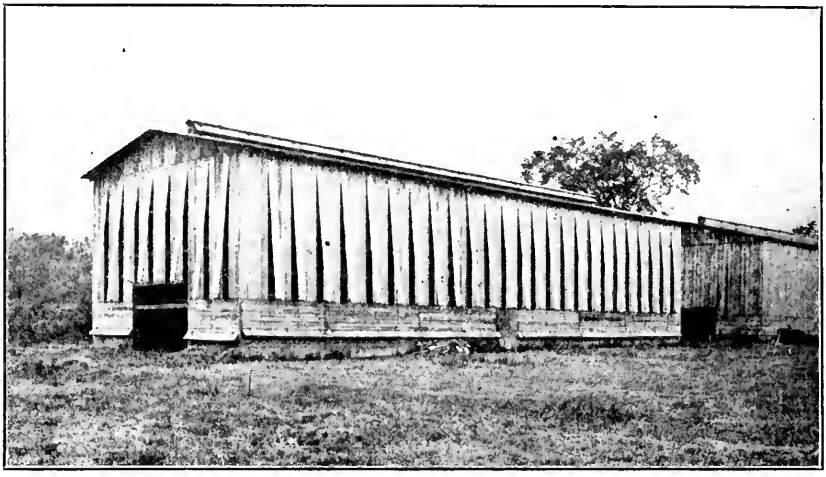

FIG. 4.—Moderate-sized barn with low, flat roof and ventilator extending along the peak of the roof, especially adapted for the use of artificial heat in curing.

We have here outlined a means for accomplishing this object, which makes it possible to cure cigar tobacco under uniformly favorable conditions regardless of the outside weather.

SUMMARY.

Methods of curing have not kept pace with the advances made in other features of cigar-tobacco production and are still comparatively crude. Curing involves important changes in the composition of the leaf other than the loss of water, and a clear distinction is to be made between curing and mere drying. The process is dependent on the life activities of the leaf cells and is essentially a process of starvation.

To insure good curing, the leaf tissue must not be killed or injured by freezing or by bruising before being placed in the barn, the temperature in the barn must be moderately high, and the rate of drying must not be too rapid during the first stages of the process.

The disease known as pole-sweat, which is merely a decay of the leaf, is due to excessive moisture in the barn after the leaf has been yellowed. This disease can be readily controlled by the combined use of heat and ventilation.

The application of artificial heat under proper conditions does not injure the quality of cigar tobacco, but on the contrary insures better curing, especially as regards the color of wrapper leaf. It has given particularly good results with picked or primed tobacco.

To apply artificial heat effectively and economically requires a reasonably tight barn, and adequate ventilation must be provided to control properly the humidity. The heating system should have sufficient capacity to maintain in the barn a temperature from 15 to 20 degrees above that of the outside air.

Open charcoal fires are used successfully in curing shade-grown tobacco, but charcoal is an expensive fuel, the supply is limited, and properly to care for the large number of fires required is a laborious task. This method of applying heat would be decidedly more expensive in the case of ordinary picked or primed tobacco and when tobacco is cured on the stalk.

A method has been devised for applying artificial heat by means of a system of furnaces and flues in which wood is used as fuel. In this method a furnace and set of flues are required for each "bent" or 16-foot section of the barn. An important feature of the system is a ventilator extending along the peak of the roof. Details regarding the construction and use of this system have been outlined. It has been fully demonstrated by tests conducted on a large scale that this method gives excellent results in curing, especially in the case of tobacco harvested by picking the leaves from the stalk.

Moderate-sized barns with low, flat roofs, which can be completely filled with tobacco in one or two days, are best adapted to the use of artificial heat in curing.

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